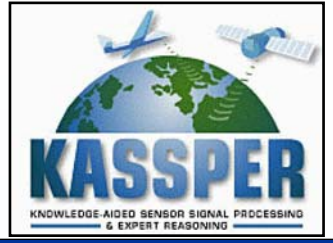

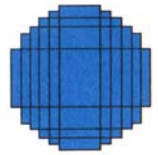

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Knowledge Acquisition and Exploitation to Enhance STAP Performance

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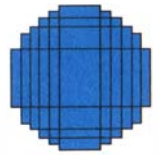
Presented by: Allan Corbeil
Dr. Charles Morgan
Richard Pierro
at: KASSPER Workshop
Las Vegas, NV
on: April 15, 2003

Introduction

- **STAP performance can be enhanced by exploiting thematically/spatially accurate and temporally current Digital Elevation Maps and Land Use/Land Cover databases**
  - Prefilter known clutter interference using covariance model
  - Exclude resolution cells from covariance estimate
  - Delimit surveillance area to where movers are likely
- **Extract knowledge that can be utilized in advanced STAP algorithms being developed by TSC and other KASSPER researchers**
  - Full and reduced dimension STAP architectures
- **Improve the accuracy of existing data bases through sensor signal processing**
  - DEM generation and strong scatterer geolocation from GMTI dwells
  - On/off-board SAR and Interferometric SAR image exploitation

DEM Generation Techniques



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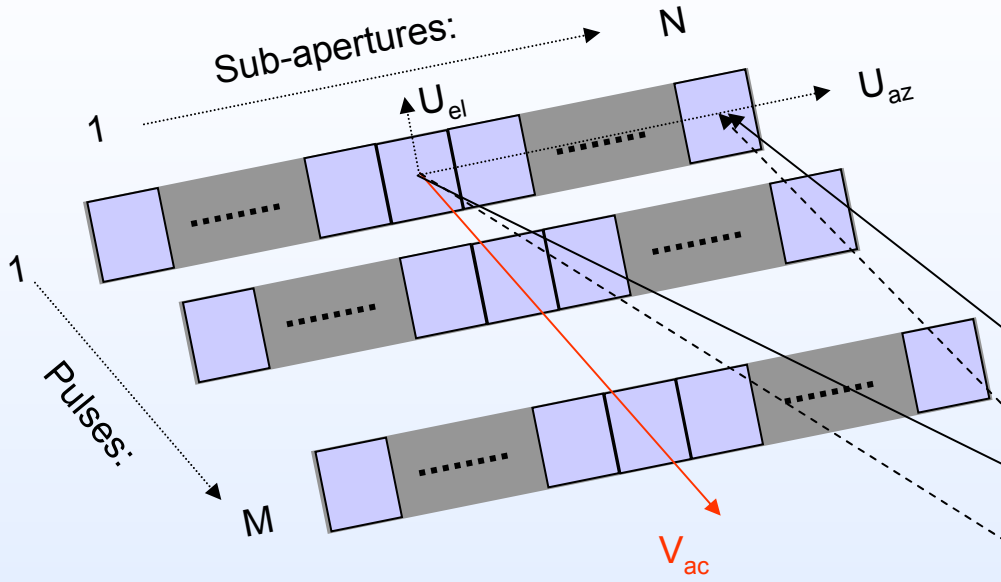
- **More accurate DEMs can benefit STAP in several ways**
  - Improved mapping of known scatterers (discretes and movers) from object database into GMTI radar resolution cells for censoring
  - Better prediction of shadow regions and strong clutter backscattering geometries from sloped terrain to select secondary data sets
- **TSC is investigating both stereo and interferometric processing of GMTI clutter maps**
  - Stereo processing is based on correlating the GMTI clutter maps collected on two flight legs which have different elevation look angles
  - Interferometric processing is based on phase difference from elevation diversity provided by aircraft pitch and widely-spaced horizontal apertures
- **Utilizing SAR-based GMTI simulation to evaluate DEM generation accuracy for specific sites where SAR imagery is available**
  - Synthesize CPIs for arbitrary sensor platform position

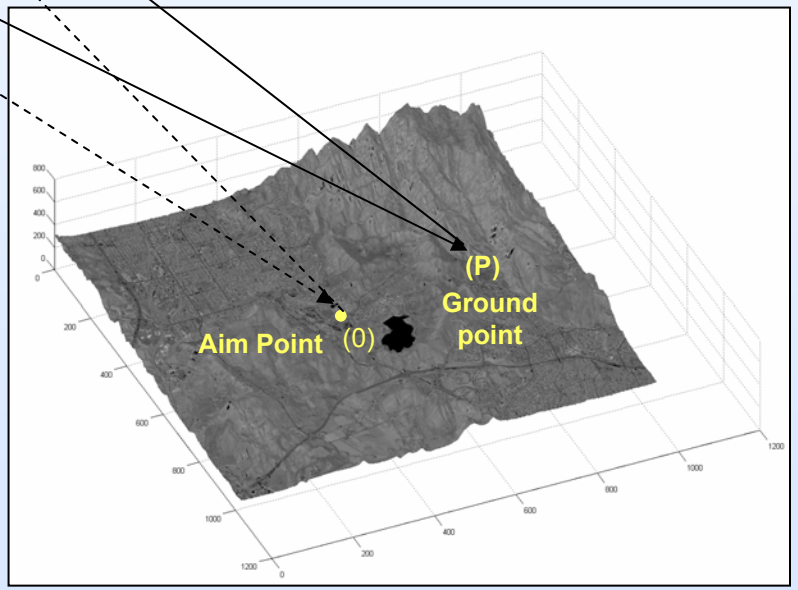
SAR-Based GMTI Simulation

- **TSC is utilizing ERIM IFSAR data to simulate GMTI clutter maps with high fidelity to evaluate DEM generation accuracy**
  - Provides registered SAR magnitude and terrain height with 2.5 m postings and Level 3 DTED accuracy
- **Model radar characteristics and 3-D geometry to produce data cubes (pulse x range x aperture)**
  - Slant range/squint angle - Multiple apertures
  - Antenna beam footprint - Internal clutter motion
  - Range/Doppler resolution - Clutter amplitude distribution
  - Radar 3-D position and velocity - Receiver noise
- **Data can also support investigation of techniques to exploit SAR imagery to enhance STAP performance**

Multiple Aperture Geometry for SAR-Based GMTI Simulation



SAR Magnitude Overlayed on DEM



SAR-Based Simulation of Range-Doppler Maps (2.5m Postings)

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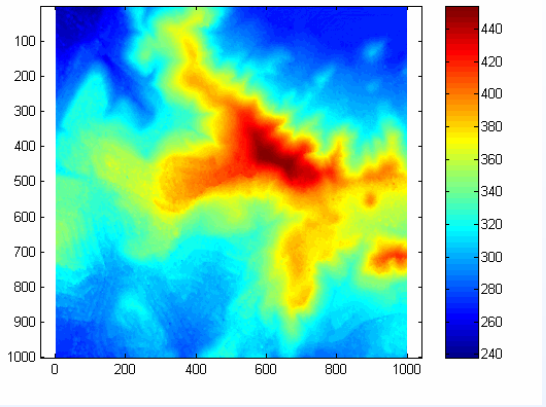
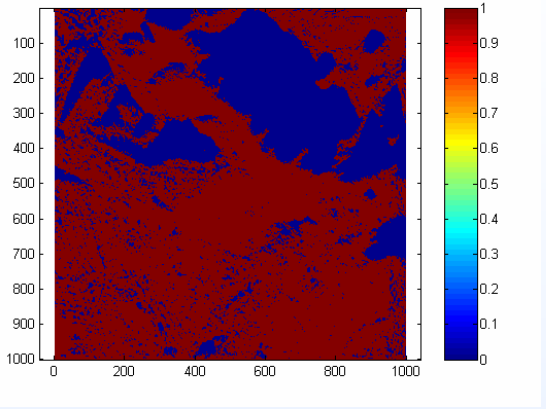
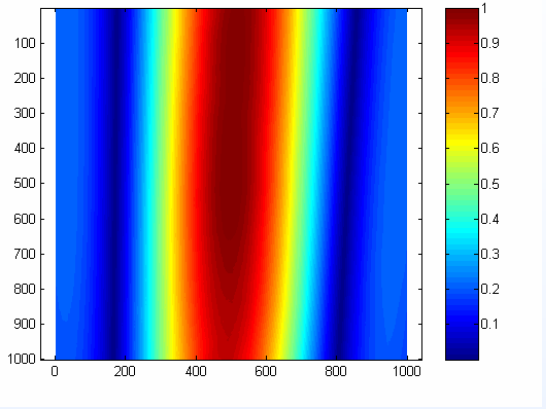


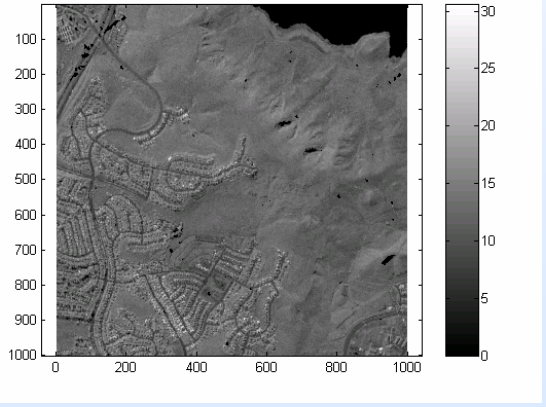
DTED (m)



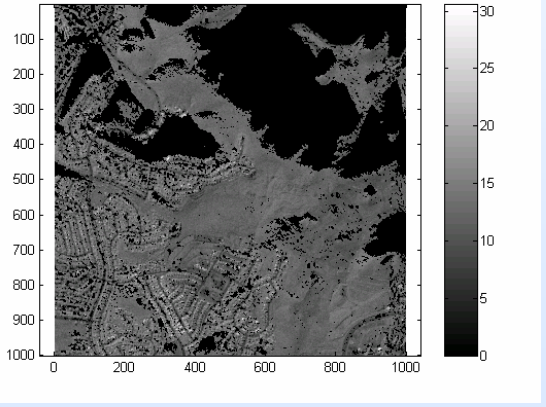
Shadowing (0,1)



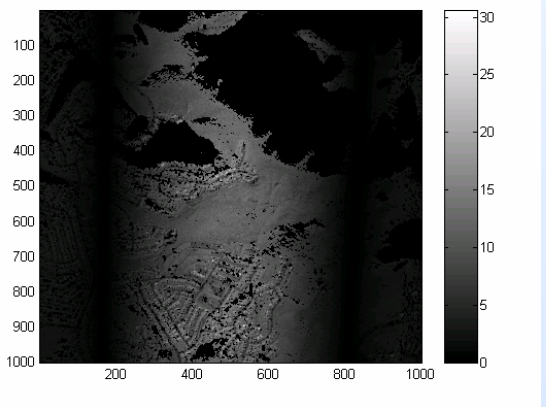
Antenna Gain (0-1)



SAR Magnitude (dB)



Shadowed Magnitude (dB)



Shadowed Magnitude with Antenna Gain (dB)

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Effect of CPI Length on Simulated Range-Doppler Maps

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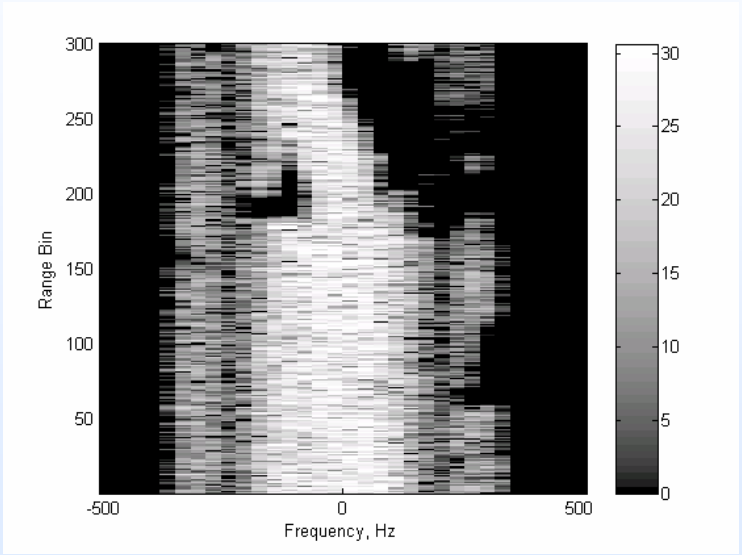
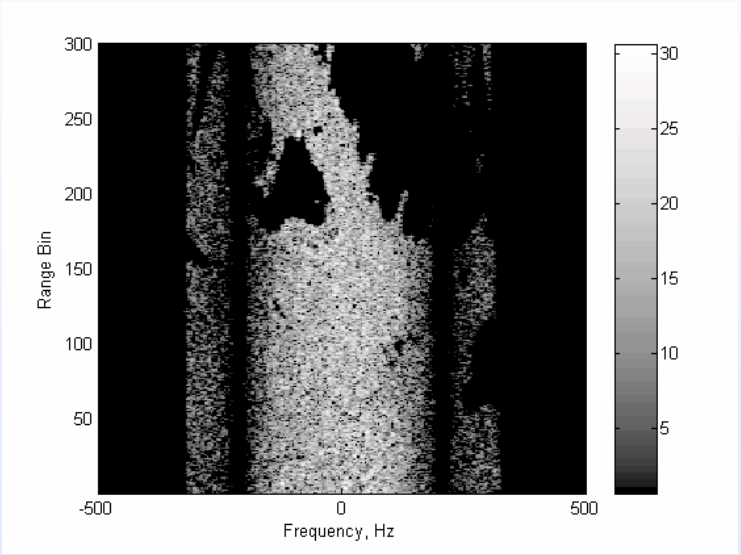
- **GMTI map has similar features to original SAR image**
  - Can discern shadow regions and water boundaries when present
  - Different terrain types produce unique texture that can be exploited for map registration



32-Pulse CPI, 1 kHz PRF, Aperture #1



256-Pulse CPI, 1 kHz PRF, Aperture #1

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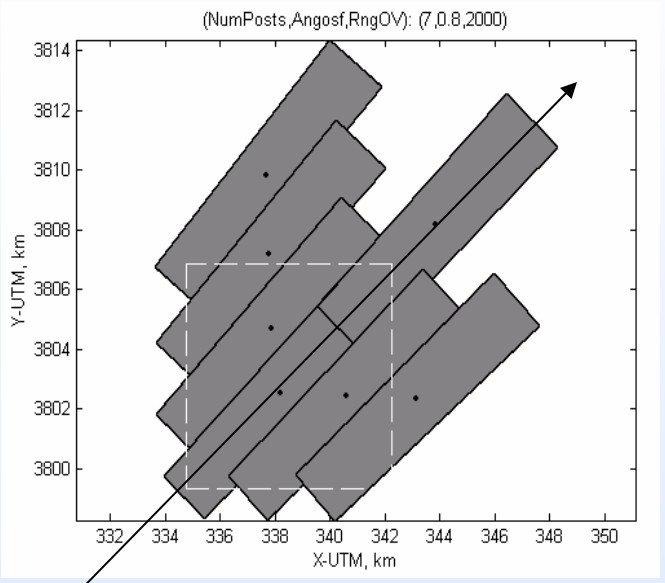
Stereo Processing Investigation

- **Defined nominal race-track surveillance path for single or multiple platforms to cover region of interest**
  - Altitude diversity to maximize elevation difference
  - Beam tiling to cover region of interest
- **Investigating three modes of operation**
  - Single set of MTI dwells at leg midpoint
  - Average MTI dwells over entire leg
  - Tomographic processing over entire leg to enhance cross-range resolution
- **Studying effect of dwell length and averaging on resultant DEM accuracy**
  - Same GMTI dwell versus longer CPI
  - Averaging reduces clutter scintillation and increases effective CNR
  - Collecting statistics over multiple passes could also benefit STAP

Tiling of Region of Interest



Preliminary Stereo DEM Generation Results

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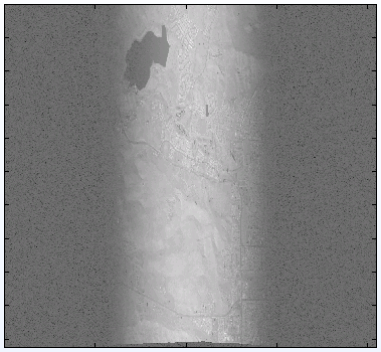
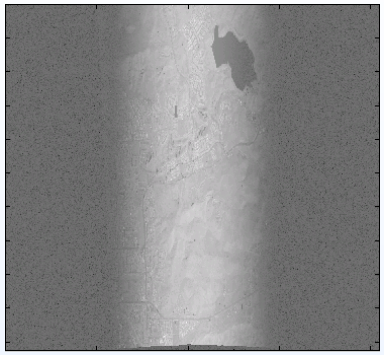
SIMULATED MTI CLUTTER MAPS

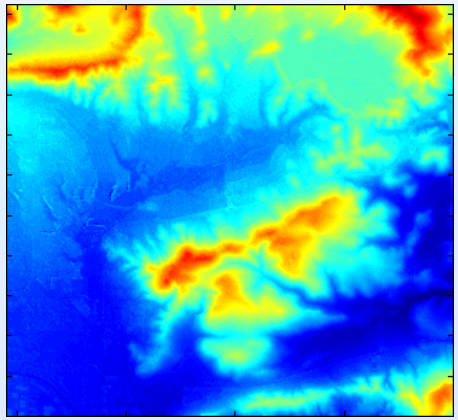
IFSAR MAGNITUDE



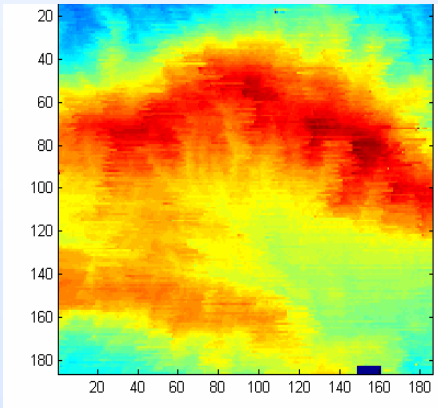
LOOK-1



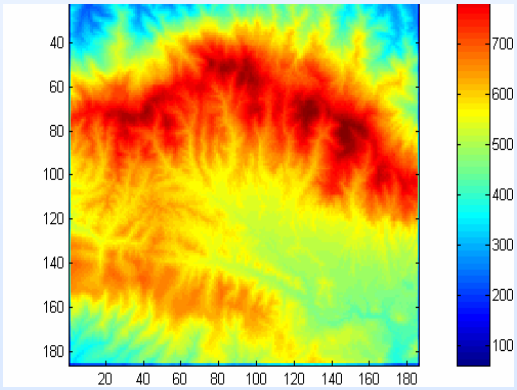
LOOK-2



IFSAR HEIGHT



ESTIMATED DEM



LEVEL-3 DTED

Enhancement of MTI Cross-Range Resolution through Tomographic Processing

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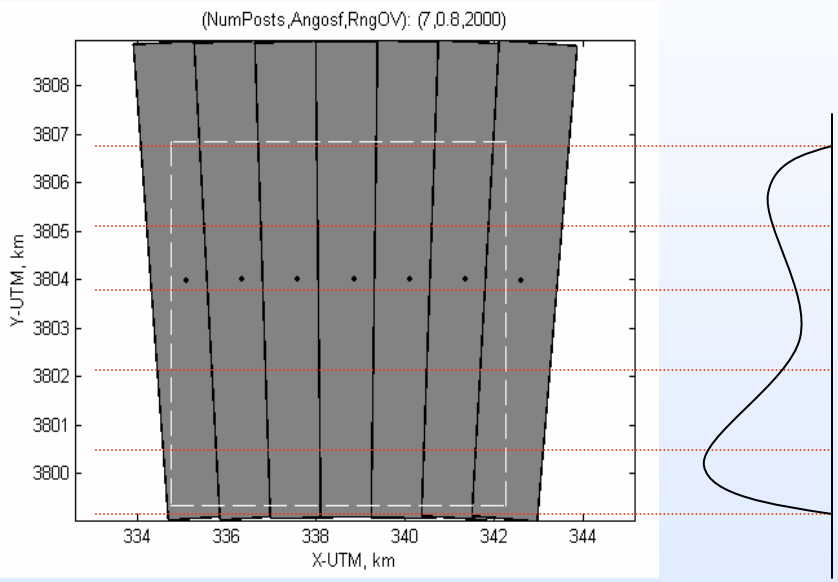
- **Cross-range resolution is much coarser than down-range resolution for typical MTI maps**
  - KASSPER/MCARM = 200x
  - Joint STARS = 20x
- **Averaging MTI maps sharpens cross-range by overlapping footprints at different aspect angles**
  - Effective only for limited range of aspect angles
- **Noncoherent tomography offers greater cross-range resolution enhancement for stereo processing**
  - Form range shadow graph at each aspect angle

    (radon transform)
  - Filtered back-projection of shadow graphs are accumulated
  - Correlate the sharpened MTI maps to derive height information (stereo processing)

Beam Tiling **Shadow Graph**



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Examples of Noncoherent Tomographic Processing

20-to-1 Cross Range Blurring

Ideal Case: No Thermal Noise, Shadowing, or Target Fluctuation with Aspect

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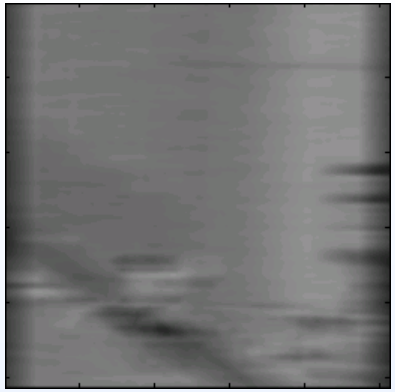
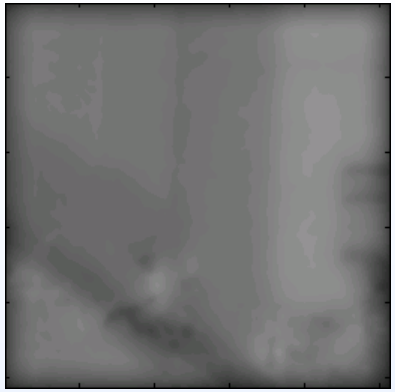
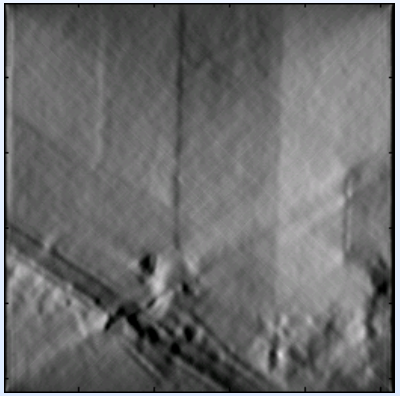
High Resolution SAR Map



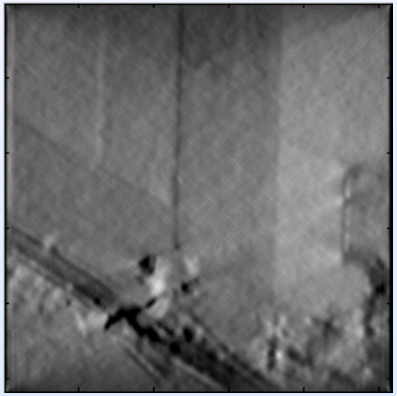
Single-Look MTI Map



Average MTI Map



120 deg



140 deg

160 deg

180 deg

TOMOGRAPHIC ANGLE

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Exploitation of Interferometric Imagery or SAR/Registered DTED

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- **Can provide information on strong scatterers that interfere with nearby weak target signals**
  - All discretes are not in database (new structures, parked vehicles, natural objects)
  - Strong distributed terrain backscattering (near-normal orientation, dense vegetation)
- **Requires SAR and GMTI data from same region to investigate concepts such as:**
  - Excising resolution cells with strong clutter in SAR image from secondary data set
  - Adaptive detection thresholding based on SAR amplitude statistics or textural features at corresponding location
  - Prefiltering of strongest clutter regions found in SAR image
  - Select secondary data set based on terrain type determined from SAR
- **Utilizing SAR-based GMTI simulation for algorithm development**

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Example of Using SAR and DTED to Identify Strong Scattering Regions

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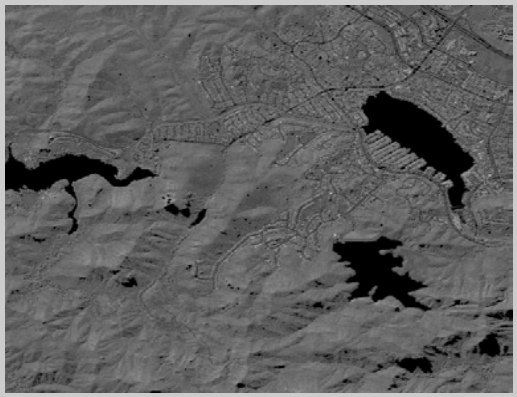
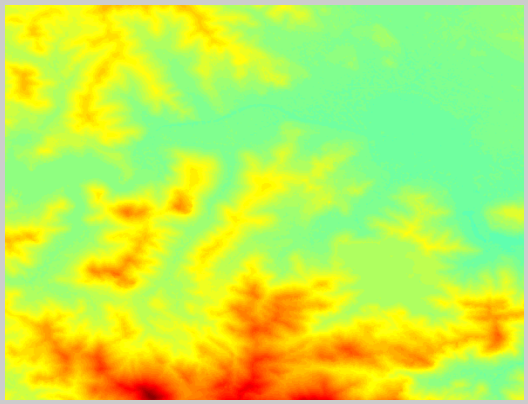
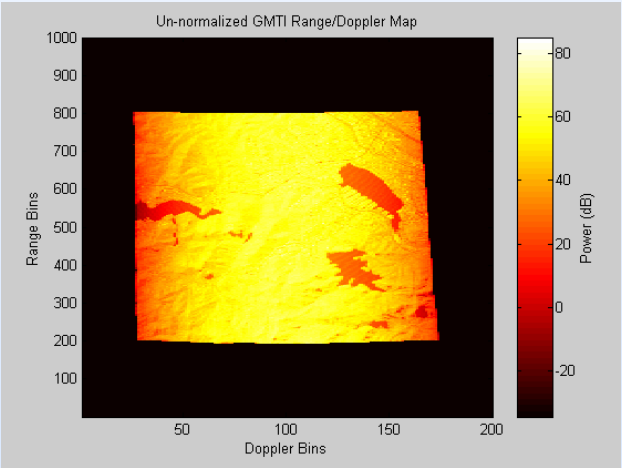


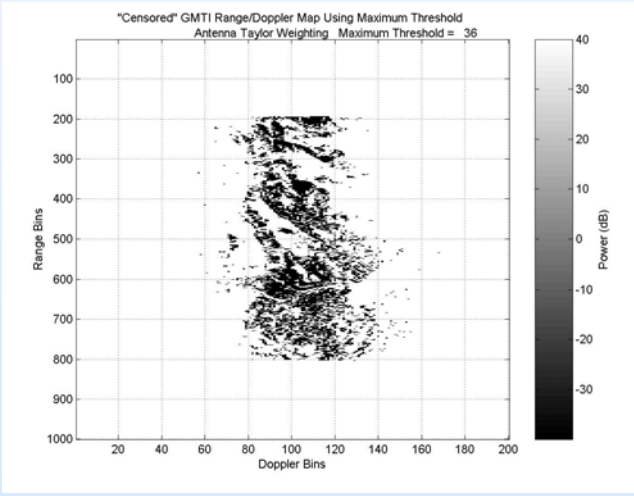
SAR Imagery: 3 m x 3 m Resolution



Level-3 DTED



Synthesized GMTI Clutter Map: 10 m Range, 5 Hz Doppler Resolution



GMTI Range/Doppler Cells Whose Corresponding SAR Magnitude Exceeds Threshold

Advanced Angle/Doppler Estimation Techniques

- **Improve geolocation of large discretes and movers to enhance STAP performance**
  - Excise corresponding resolution cells or prefilter these strong returns from secondary data set
  - Predict detections from azimuth and Doppler sidelobes to reject false alarms
- **Investigating several methods to operate with full or reduced dimension STAP**
  - MLE, Minimum Variance Estimator, and Prony's method
  - Compare with conventional beam and filter splitting
- **Associating STAP MLE detections with ground truth from 2003 KASSPER data cube for preliminary investigation**
  - Full dimension STAP with censoring of discretes and movers
  - PRI-staggered, post-Doppler STAP architecture

Knowledge of Terrain Cell Reflectivity Aids in Associating False Alarms with Strong Distributed Clutter

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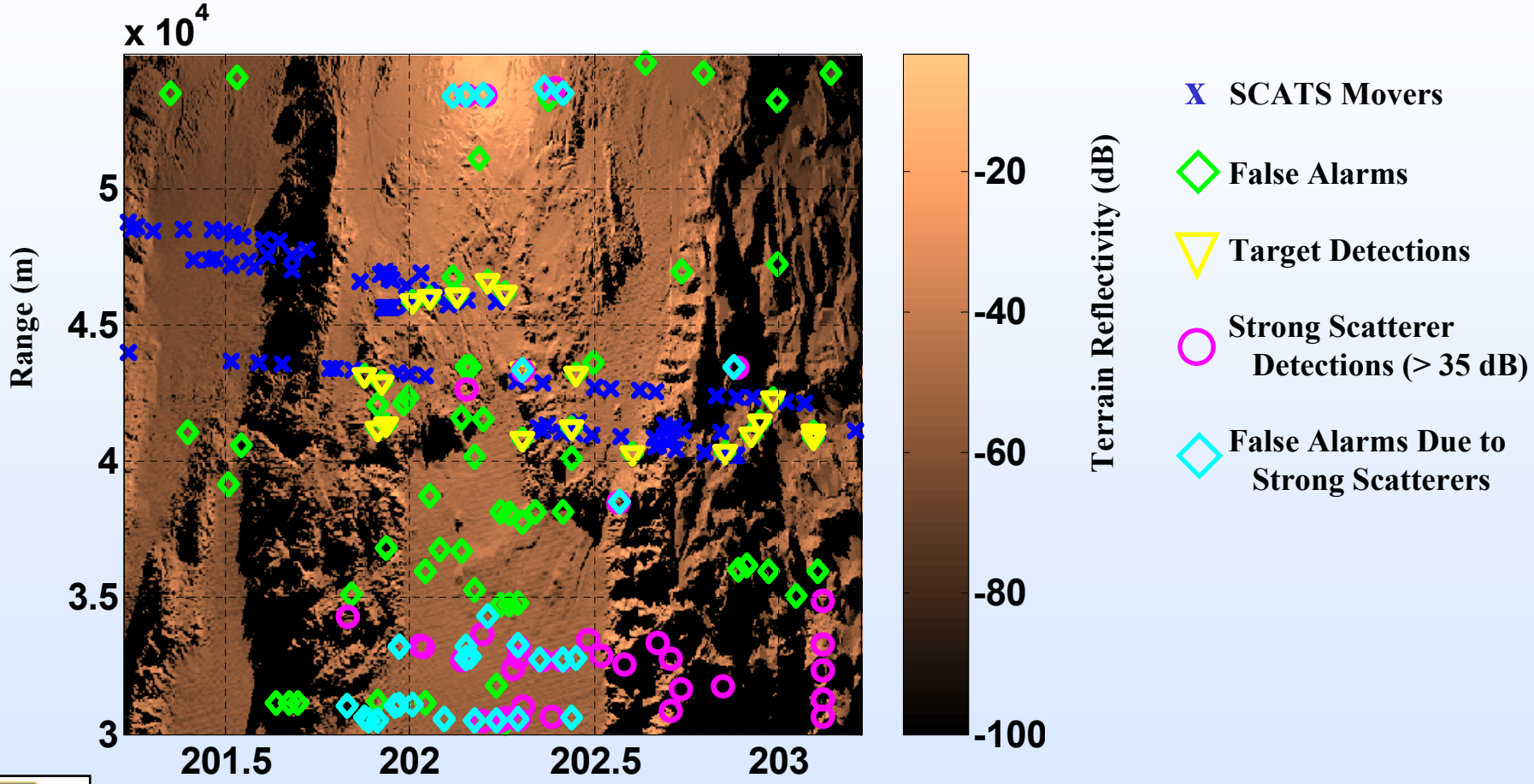
Range vs. Azimuth: SCATS Ground Truth, MLE, 5 PRI Staggers, Discrete/Target Censoring, 10^{-7} Pfa



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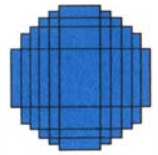
Planned Work



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- **Quantify the benefits of improved knowledge on STAP performance**
  - Increased DEM accuracy from stereo or interferometric processing
  - Reliable LU/LC map from GMTI clutter or registered SAR imagery
  - Improved location of discretes and terrain backscattering
- **Evaluate sensor, processing and platform requirements for knowledge acquisition**
  - Determine optimal GMTI dwell length, aperture size, and flight profile
- **Demonstrate stereo DEM generation from measured clutter data**
  - Joint STARS flights with elevation aspect change
- **Use GMTI simulation to develop techniques that exploit SAR/DTED information and enhance STAP performance**
- **Investigate array calibration techniques**
  - Exploit knowledge of distributed/discrete clutter or active RF sources
  - Correct channel amplitude and phase imbalances